EXPERIMENTAL STUDY OF MOTOR ABILITIES OF CHILDREN IN THE PRIMARY GRADES

BY

BUFORD JENNETTE JOHNSON

A DISSERTATION

Submitted to the Board of University Studies of The Johns Hopkins University in Conformity with the Requirements for the Degree of Doctor of Philosophy

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EXPERIMENTAL STUDY OF MOTOR ABILITIES OF CHILDREN IN THE PRIMARY GRADES

I. INTRODUCTION

The careful study of motions made by adults in the industrial vocations has served to give a scientific basis for almost revolutionary policies and methods in the economic world. The popular question of vocational guidance involves various tests of motor ability and control.

The more important investigations of motor abilities and of learning processes have concerned adult activities. Inquiries including tests of adolescents and of school children in the elementary grades have usually been limited to the single test or to a few repetitions. For a study of individual variation in meeting new situations, as indicative of previous experience, or for detecting extremes in the normal range of distribution, the single test is most valuable. For the larger number in the middle range, it is generally agreed that special practice makes a measurement of a process a far truer one.

Because of their attitude to the novelty of the experiment, with young children it is almost impossible to obtain results from single tests that will give any positive indication of actual motor abilities. The tendency to overestimate the value of results obtained from particular experiments becomes dangerous when these results are universally applied and used to justify some procedure, such as for diagnostic purposes in vocational guidance.

The problem of this investigation is the determination of motor abilities of children between the ages of four and ten years, dealing specifically with the improvement by practice in motor-coördination and the effect upon the

learning process of different intervals between practice periods. Rate and precision of voluntary movement, measurement of involuntary movement, simple and discriminative reaction times are treated. Sex differences, fatigue effects, and preference in hand used are also studied.

II. HISTORICAL SKETCH

There is no scarcity of data as to tests of the kind undertaken, but varying technique and purposes have given a preponderance of unconfirmed experimental results.

1. Speed of Movement

(1) *Practice Effects.*

Results of the tapping test used with adults in practice series by Hollingworth (11),[1] Wells (21), Marsh (16), and Dresslar (7), show improvement due to practice, varying in rate and amount with individuals, conditions, and duration of experiment. The rate is not uniform, Wells (21) reporting that the curve fluctuates more after a week than at the beginning. Hollingworth (11) concludes that there is very low correlation of first trial with final capacity.

All previous investigators show that rate increases with age, with some evidence of retardation at periods of retarded physical growth. No prolonged experimental work has been done with children so far as the writer knows.

(2) *Sex Differences.*

Bryan (5) found that in single tests on children from five to sixteen years old boys were slightly superior, except at thirteen when the girls excelled. This latter finding, as was suggested in his paper, might be explained by the earlier maturity of the girls.

Bolton (4) studied rapidity of movement in groups selected according to social status. Tapping with finger on key was form of test used. Five trials with each hand, duration of each trial 5 seconds, constituted an experiment. Records of one experiment for thirty of each sex, eight to nine years old, belonging to a superior social group, were

[1] The numbers in parentheses refer to the list of references given in the Bibliography.

compared with those for the same number of inferior social standing. He concludes that "girls are uniformly better than the boys. The girls in the good class do not show greater or even quite as much superiority over the boys of the same class, as the girls of the poor class show over the boys of the same class."

Gilbert (8) gave single tests with right hand to one hundred children of each age, fifty of each sex, from six to seventeen years old. Rapidity was measured by tapping on telegraph key in connection with chronoscope for forty-five seconds. Records were taken only of first five and last five seconds. He found that boys excel in speed. He gave similar tests to Iowa school children. Results there showed a slight superiority for girls during the earlier years.

For ages twelve and a half to thirteen and a half years Burt and Moore (6) found that 69.8% of boys exceeded median speed of girls. Among adults, Thompson (20) found that 88% of men tested exceeded the median speed of women.

(3) *Fatigue Effects.*

Wells (21) found among adults that practice brings warming up, showing in increased immunity to fatigue, and that initial rate and fatigue loss are negatively correlated.

Dresslar (7) reports that with subject working at "limit of practice" sensations of fatigue ceased, but objective phase persisted.

Gilbert (8) found that susceptibility to fatigue decreases uniformly for both sexes with increase in age; that boys tire more quickly than girls, but their initial superiority was sufficient to over-balance the greater percentage of fatigue loss and make their net efficiency greater. Among the Iowa children he found practically no difference between sexes in fatigue loss during last five years, from twelve to seventeen.

(4) *Index of Right-handedness.*

Wells (21) reports for adults no greater improvement by

practice with left hand than right hand, but that right hand tends to warm up more than left hand; hence is more immune to fatigue. He finds the relationship between right and left hand more variable in women than in men and their hands farther apart in ability. These conclusions are based upon only two experiments, in first of which women surpassed men with right hand but elsewhere were inferior.

Woolley and Fischer (23) found superiority in tapping test more reliable an indication of left-handedness than superior steadiness or strength.

Bolton (4) found no significant difference between right and left hand for "good" and "poor" subjects.

2. Involuntary Movement.

(1) *Practice Effects.*

It is generally recognized that there is little improvement by practice in steadiness test, unless by a trick in method for control of respiration. Since control of muscles to prevent moving of body, co-operation of subject, and physiological processes affect results so greatly, satisfactory control, especially for children, is difficult to establish. For children of the age considered various forms of tests have been used and for varying purposes. No data actually comparable is available, so far as writer is aware.

Hancock (10) concludes from use of ataxiagraph that adults have 5.8 times the control of children from five to seven years old.

(2) *Sex Differences.*

Distinct sex differences are not evident. McDonald (15) and Hancock (10) found girls steadier than boys. In tracing test Bryan (5) reports a slight superiority for boys, while Bolton (4) found that girls excel.

Woolley and Fischer (23) used a form of test similar to ours with seven hundred and fifty-three children fourteen years old, and one year later three hundred and ninety-two boys and two hundred and eighty-seven girls were retested. Their conclusion was that "girls are clearly superior to the boys in steadiness."

(3) *Index of Right-handedness.*

Variations are so great in results and a shift in superiority from one hand to another occurs so often that the index of right-handedness is not very reliable. Woolley and Fischer (23) found forty-eight boys and thirty-one girls superior with left hand in first test. Of these, forty-six boys and twenty-nine girls were retested a year later. Only ten boys and five girls remained left-handed, while twenty-five new subjects showed superiority with left hand in second test.

3. Simple and Discrimination Reaction Times

Gilbert (8) reports reaction times for children from six to seventeen years old. The median value for ten trials was accounted the measurement of a subject's reaction time. Averages of these values were taken to represent the different ages. Discrimination preceded simple reaction. He found boys quicker than girls, except for discrimination reactions at age of six, and a decrease in reaction time with increase in age.

4. Accuracy of Movement

Probing or thrusting movements in aiming have been frequently used for measuring precision, as in Thompson's (20) target test on adults, in which she found better coordination on part of men.

We have not been able to find any prolonged study of children. Bagley (1) studied accuracy in aiming at a target—bull's eye, 10 mm. in diameter—from a distance of two meters. The experiment consisted of three trials, ten marbles thrown at a trial. Errors in millimeters as to distance from center were computed. Ages of subjects varied from eight to seventeen years. He reports that "boys slightly surpass the girls in motor ability." There is a gradual increase in ability with increasing age.

5. Distribution of Practice Periods in Learning

Leuba and Hyde (13) made four divisions of subjects in testing progress in writing English prose in German script. The daily and alternate-day practice groups made better records than the twice-per-day or every-third-day groups.

Lashley (14) found that college boys show greater improvement in skill in archery for practice periods of five shots per day, than for a greater number of shots.

Munn (17) carried out a series of ten substitution tests, one test each day, on twelve children of an average age of eight years. Six were taken in the morning, six in the afternoon, and while slower in the beginning, children make greater but more irregular gains than adults. From her records of normal school pupils given varying intervals between practice periods in this test, she concludes that short and frequent practice periods are most valuable.

Murphy (18) found that normal school girls in practice at javelin throwing made greater gains when given weekly or alternate-day practice than through a distribution of five times per week.

6. Summary

As a summary of the main points in the findings of previous investigators we may note:

That all results show a marked increase of motor control with age.

That the majority report a slight sex difference in favor of boys in rate and accuracy of movement; in favor of girls in steadiness. Loss by fatigue is greater for boys and these sex differences are more marked with increasing chronological age.

That the index of right-handedness varies with age, being more pronounced in childhood.

That there is disagreement as to the most economical distribution of practice periods in learning, but somewhat stronger evidence in favor of short and frequent periods, with preference given to morning hours for children.

III. PROCEDURE

The following tests were made by the writer. Similar tests had been given previously both to children and adults and satisfactory methods of control and procedure carefully studied.

In the first grade of a public school in Thomson, Georgia, where the pupils are of varied social status, such as is found in a small Southern town, eighteen girls and sixteen boys between the ages of five and nine years were given the Steadiness Test on September 16 and 17, 1915. The following Monday at the same hours, from 9 to 12 o'clock, a series of tests in tapping were begun and continued through three weeks, omitting Saturdays and Sundays. The Monday following the completion of this practice series in tapping a second steadiness test was given. Detailed methods and apparatus are described under the special headings for each form of test.

The measurement of simple and discriminative reaction times was made in The Johns Hopkins Psychological Laboratory. The difficulties in arranging for many children to work there caused the number of subjects to be small and the distribution such that sex differentiation could not be of much value. The study of the factors entering into this test upon young children has been highly profitable.

The tests in precision of movement as measured by aiming at the center of a system of concentric circles were made upon children of the first and second grades of a public school in Baltimore. Only normal children, free from physical defects as determined by medical inspection, were tested. They came from the poorer district of the city and in many cases of foreign parentage. These children were always eager to take part in the "game." Groups of

twelve, six boys and six girls, were selected for different practice periods, varying from five days successively in one week to once in two weeks. Tests were begun November 29, 1915, and continued until middle of April, 1916.

Further details of experimental procedure are discussed later in connection with results of various forms of tests.

IV. RATE OF VOLUNTARY MOVEMENTS

1. Apparatus

The tapping test similar to that described in Whipple's (24) Manual was used for testing quickness of movement. The board is a brass plate four inches square. The stylus, weighing 19 grams, had a metal needle ⅛ of an inch in diameter, 1¼ inches long, with a wooden handle 4 inches long, ⅜ of an inch in diameter. Board, stylus, and Ewald Chronoscope were so wired with battery that contact of stylus with plate recorded a tap. By stop-watch, number of seconds required for one hundred taps was scored. Time required for first fifty taps was also noted to secure an index of fatigue. Kymograph record was not made, but rate of children is such the experimenter could count taps and thus kept check on record of chronoscope. This method is open to criticism as a source of error, but the personal equation was the same in each case and the differences too small for significant errors.

2. Method of Conducting Test

The board was placed upon a table near the edge and each child stood during test. In taking position some had a tendency to rest free hand upon table but this was not permitted. Blocks were used to adjust position of board for each individual, so that a comfortable position was maintained. Freedom was allowed in use of movement, resulting in combination of wrist and elbow. Each child was shown how the taps caused the hand to move on the "clock," but this was screened from sight during tapping. A few preliminary taps were given him in this explanation. He was told to tap just as rapidly as possible from the signal "Ready Now" to that of "Stop." Right hand was tested first. After a rest of thirty seconds, left hand was tested.

A room adjoining the Assembly Hall, very quiet during the hours of experimentation, was available for all the tests. Two children were taken at a time. One sat across the room from the table and there was no talking or moving about during the tapping. Throughout the entire series the children seemed ready and eager to tap, except for the desire to stop at the onset of fatigue. This desire was but poorly controlled by a few with their left hands.

3. Subjects

All the pupils from one First Grade room, between the ages of five to nine years, began the test,—nineteen girls and eleven boys. There were four girls and three boys of the higher section, who had been in school the Spring before. The others had just entered the first week in September. Only nine girls and four boys were present each day of the fifteen days on which tests were made. There are thirteen girls and six boys whose records are reported, their absences ranging only from one to two days. Height, standing and with shoes, weight, and age of each subject were recorded. In physical measurements they approximate closely the norms in stature and weight established by Boas (3) and Smedley (19). The girls averaged six years, eight months, twenty-nine and two-thirteenths days in age, ranging from five years, ten months, fourteen days to seven years, eight months, sixteen days. The boys averaged six years, eight months, twenty-six and two-thirds days, ranging from six years to seven years, one month and twenty-eight days. There is a difference of 2.48 days in averaged ages, while the range is six months greater for girls.

4. Computation of Results

The daily averages of time in seconds required for first fifty and second fifty taps with each hand were computed for both sexes. The learning curves are plotted from averages for the complete test, one hundred taps.

The individual averages for entire series were computed. With these as measurements the averages and mean variations for sex differentiation were made. In other words, the average of individual averages was used as measure of group. Median value was also found and probable error[1] obtained for determining significance of averages.

The difference in daily averages of time required for first and second fifty taps was used to indicate loss by fatigue.

5. Results

The table below shows the daily averages. T is total time for one hundred taps. D is difference in time for first and second fifty taps.

(1) *Practice Effects.*

It is clearly shown that there is marked improvement with practice. During the first six days a great percentage of the entire gain is made. For the next five days there are irregularities and the downward tendency of curves for the last three days indicates that a somewhat higher final level of efficiency would have been attained through further practice.

The average rate from all trials is not attained until the sixth day for girls, the fifth day for boys. The initial records of girls for one hundred taps ranged from 22 to 45 seconds with right hand; 25 to 55 seconds with left hand. For boys, 26 to 39 seconds, right hand; 34 to 38 seconds, left hand. The group of girls had two subjects at each extreme and the central group had a range of only 3.5 seconds as compared with 23 seconds for entire group. The group of boys clusters more closely about the median and seems of rather mediocre ability when judged by initial trials, yet they finally attained a rate, based on time for first fifty taps, superior to Gilbert's seven-year-old boys, whose records are based on first five seconds.

[1] P. E. was obtained by following formula: P. E. $= 0.8453 \times$ A. D., where A. D. represents the average deviation from the average of individual measurements.

TABLE I

SHOWING DAILY AVERAGES IN TAPPING TEST

Day	Boys—Time in Seconds				Girls—Time in Seconds			
	1st 50 Taps	2d 50 Taps	Total	Diff.	1st 50 Taps	2d 50 Taps	Total	Diff.
1—R.H.	15.75	17.25	33.00	1.5	13.58	15.00	28.58	1.42
L.H.	15.33	20.33	35.66	5.0	15.00	17.29	32.29	2.29
2—R.	15.30	15.66	30.96	0.36	12.38	14.23	26.61	1.85
L.	15.66	18.41	34.07	2.75	14.15	17.30	31.45	3.15
3—R.	12.33	13.16	25.49	0.83	11.11	13.34	24.45	2.23
L.	14.41	16.25	30.66	1.84	13.43	16.20	29.63	2.77
4—R.	10.00	13.40	23.40	3.40	10.22	13.04	23.26	2.82
L.	12.58	16.83	29.41	4.25	12.11	15.47	27.58	3.36
5—R.	10.15	12.16	22.31	2.01	10.31	12.54	22.85	2.23
L.	13.08	15.00	28.08	1.92	12.46	15.19	27.65	2.73
6—R.	9.66	12.33	21.99	2.66	9.85	12.07	21.92	2.22
L.	12.83	14.66	27.49	1.83	12.17	15.24	27.41	3.07
7—R.	10.13	12.03	22.16	1.9	9.72	11.95	21.67	2.23
L.	12.73	16.50	29.23	3.77	11.84	14.73	26.57	2.89
8—R.	10.13	12.03	22.16	1.90	9.75	12.32	22.08	2.57
L.	12.90	16.16	29.06	3.26	11.65	13.71	25.36	2.06
9—R.	9.58	13.03	22.61	3.45	9.31	11.46	20.77	2.15
L.	12.00	15.33	27.33	3.33	11.64	14.74	26.38	3.09
10—R.	9.66	11.83	21.49	2.17	9.12	11.18	20.30	2.06
L.	11.83	14.83	26.66	3.00	11.35	14.00	25.35	0.65
11—R.	9.73	11.43	21.16	1.70	9.57	11.20	20.77	1.63
L.	11.83	15.00	26.83	3.17	11.10	13.66	24.76	2.55
12—R.	9.43	11.83	21.26	2.40	9.20	10.87	20.07	1.67
L.	12.50	14.16	26.66	1.66	11.47	13.61	25.08	2.15
13—R.	10.10	12.06	22.16	1.96	9.33	10.69	20.02	1.36
L.	12.00	14.66	26.66	2.66	10.83	13.53	24.36	2.70
14—R.	9.72	12.28	22.00	2.56	9.24	11.74	20.98	2.50
L.	11.80	15.20	27.00	3.40	11.20	13.16	24.36	1.96
15—R.	9.40	11.38	20.73	1.93	8.18	9.90	18.08	1.72
L.	13.00	14.00	27.00	1.00	11.10	12.71	23.81	1.61
Average R.	10.73	12.79	23.52	2.049	10.06	12.10	22.16	2.046
L.	12.96	15.82	28.78	2.856	12.10	14.70	26.80	2.469

Table II shows the individual ranking in first trials and in averages obtained as a measure of final efficiency.

Considering the right hands, it is noticeable that the boys making best and poorest records on first trials make the least change in final ranking. This same tendency is noted in the girls and is more pronounced in the more inefficient group. There was no case in which there was no change in ranking, this varying from one step to two for boys; from one step to six for girls.

FIG. 1. Tapping Test. Abscissa, Practice Periods. Ordinate, Time. Boys, R. H. ———, L. H. — — —. Girls, R. H. ———, L. H. — — —.

The averages for left hands show much greater variation from initial trials, this being more marked in the extremes for the boys, in which group there were no left-handers.

TABLE II

RANK IN TAPPING TEST

Boys	R. H.		L. H.		Girls	R. H.		L. H.	
	1st Day	Average	1st Day	Average		1st Day	Average	1st Day	Average
a	4	6	3	4	A	1	2	10	4
b	5	3	6	2	B	7	4	4	3
c	6	5	5	3	C	9	6	7	8
d	3	1	4	1	D	8	10	2	2
e	2	4	1	6	E	12	13	1	6
f	1	2	2	5	F	4	1	5	1
					G	11	12	8	11
					H	13	11	13	12
					I	3	7	12	13
					J	6	5	9	10
					K	2	8	3	9
					L	10	9	11	5
					M	5	3	6	7

Of the girls D was decidedly left-handed and it is not surprising that she kept her rank. E's left hand showed slight superiority over right hand in final efficiency, but was not consistently so throughout the series and drops from 1 to 6 in rank. Again there are erratic changes in ranks varying from 1 to 6 steps with no general tendency, but the two most inefficient of this group make a change of but one step.

These results show clearly that the initial trials are not indicative of actual ability but are of diagnostic value in detecting the extremes, or greatest variants in the normal distribution.

A comparison of results is not of value unless the varying conditions are carefully noted. The following tabulation for tapping with right hand shows the increase in rate with age and sex differences.

	No. Taps in 1 Sec.	Sex	Age	No. of Trials	Duration of Trial
Marsh.....	6.7	male	26–34	12	Time for 100 Taps
Burt.....	5.36	male	12½–13½	1	15 Seconds
	5.28	female	" "	1	" "
Gilbert.....	4.56	male	7	1	5 "
	4.25	female	"	1	" "
Bolton.....	6.1	male	8–9	5	" "
Bolton.....	6.13	female	8–9	5	" "
Bryan.....	4.72	male	6	1	" "
	4.25	female	6	1	" "
Our average	4.66	male	5–8	15	10 "
rate.....	4.95	female	5–8	15	10 "

The validity of the initial trial, or the average of less than five trials, as a measure of ability is again questioned by certain differences in individual records during early trials. It does not seem expedient to give all the individual records and curves, but a study of a few of the unusual ones suggests the importance of considering some of the individual differences that are completely covered up in the averages.

In general the individual curves correspond in form to

the group curve. The left-handers, as D, having very similar curves to a right-hander, save for change of place and, perhaps, less distance apart.

There was one girl, K, whose record for first day was better than that for second, third, and fourth days and final average, both with right and left hand, though she

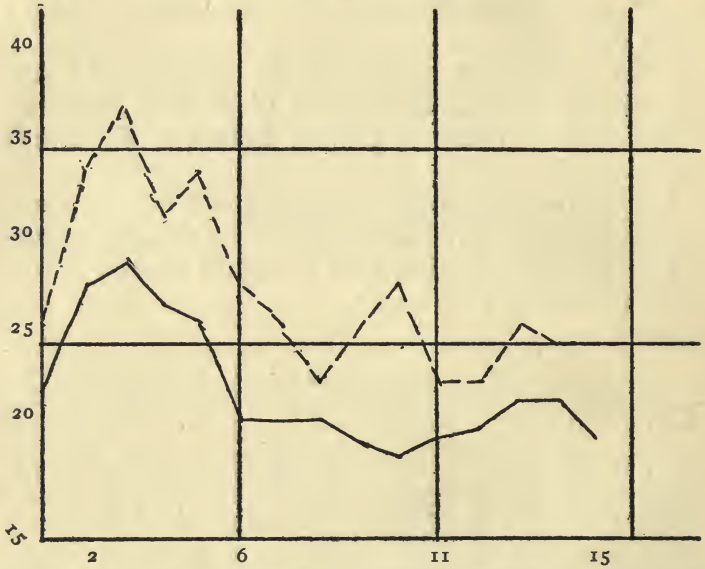

FIG. 2. Subject K. Tapping Test. Abscissa, Practice Periods. Ordinate, Time. R. H. ——, L. H. — — —.

attained a speed on several other days three seconds faster than the first day rate.

Figure 2 shows curve of individual K. If abnormal physiological condition prevailed during the three days of diminished speed it was not evident. This subject did have a cold the second week and the vitality may have been lower just preceding it.

Figure 3 shows curve for I, whose left hand was so poorly controlled. Her right hand curve is normal, her average for it being median value for group, but the hands are very far apart. She seemed to have used her left hand

but little and to be really averse to using it. Her awkward holding of stylus with left hand and variation in rate for last fifty seconds were noted. There was a tendency when

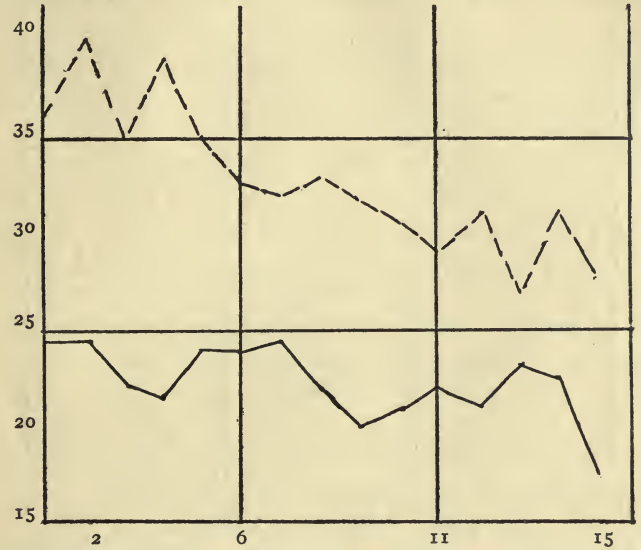

FIG. 3. Subject I. Tapping Test. Abscissa, Practice Periods. Ordinate, Time. R. H. ——, L. H. — — —.

nearly fifty taps had been made to change from holding stylus in fingers to grasping in palm; to pound slowly upon plate, and to move right hand in correspondence with left.

Figure 4 shows curve for subject H, whose initial rate was exceedingly slow and left hand also under poor control. There is here a marked resemblance in form of two curves, but the hands are far apart.

Of those tested on the first day who were present as many as nine days, four girls and four boys failed to do as well on the second day. These records showed much irregularity for several days, some not again attaining speed of first day until fourth or fifth day.

Wells's (22) interpretation of difference between first and second trials with women, who surpassed men with

right hand in first trial but were elsewhere inferior, as due to affective variability,—a sex characteristic of not being so interested after the novelty had passed away,—is not in agreement with these findings for children. It seems not

FIG. 4. Subject H. Tapping Test. Abscissa, Practice Periods. Ordinate, Time. R. H. ———, L. H. — — —.

to be a rule, but rather that individual characteristics, with perhaps environmental or physiological factors, cause such exceptions in both sexes.

(2) *Index of Fatigue.*

The difference in daily averages of time required for first and second fifty taps indicates the loss in rate from fatigue. These differences are given in Table I under Diff.

We computed the fatigue index by taking the percentage of this difference to the efficiency for the first fifty taps, obtaining the following results.

Fatigue-index for boys, R. H. 19%; girls 20%.

Fatigue-index for boys, L. H. 22%; girls 20%.

These are lower than that of 24% found by Gilbert for children eight years old, showing perhaps an increased immunity to fatigue through practice.

We also computed the average daily deviations of the fatigue loss, finding:

A. D. for R. H. Boys 0.5771; Girls 0.354.

A. D. for L. H. Boys 0.8442; Girls 0.5462.

From these we obtain the probable error[1] of the difference between the averages for boys and girls.

P. E. for R. H. 0.233; L. H. 0.345.

The difference of 0.003 for right hand is only 0.028 times its probable error; that of 0.387 for left hand, 1.12 times its probable error. We can not conclude the slight differences are significant of sex differences in loss from fatigue. The difference for left hands is of more significance and may be accounted for by the decided left-handedness of two of the girls.

The greater fatigue index for boys with the left hand is characteristic of a normal distribution. In case of girls the equality in percentages for both hands is not surprising, because of the individual variations already noted.

There appears to be no definite connection between rate and fatigue loss within the limits of this experiment. The boy and girl making best speed for one hundred taps had a relatively low fatigue index. Other subjects were irregularly arranged as to rank in rate and in loss by fatigue. In the first few trials, there is a tendency to lessen speed at the onset of fatigue, but to increase energy by pounding on plate. Practice tends to eliminate the keen sensations of fatigue and the increased force in striking.

In order to study more carefully the relation between rate and fatigue, as objectively shown by decrease for last fifty taps, two girls and one boy were given tests of longer duration in the laboratory. A series of trials, ranging from three to five, were given during one laboratory period, with intervals of ten minutes between trials. A trial consisted

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[1] P. E. of mean was obtained by following formula: P. E.$_M$ $= \frac{0.8453}{\sqrt{n-1}}$A. D., where n is total number of individual measurements, and A. D. is average deviation.

P. E. of the difference between two means, M_1 and M_2, was found as follows: P. E.$_D = \sqrt{\text{P. E.}_{M_1}{}^2 - \text{P. E.}_{M_2}{}^2}$.

of one hundred taps with right hand; after a minute's rest, one hundred taps with left hand. These children came to the laboratory once a month during five months.

Averages for individuals are given in following table.

TABLE III

	Age	R. H.				L. H.			
		(1)	(2)	T.	D.	(1)	(2)	T.	D.
W. girl.....	10	8.98	10.31	19.29	1.33	9.71	11.60	20.77	1.88
X. girl.....	8	8.17	9.00	17.17	0.83	7.71	8.51	16.22	.80
Y. boy.....	8	9.03	9.47	18.51	0.44	8.63	10.41	19.09	1.73

(1) and (2) columns have number of seconds required for first and second fifty taps. T. is total of (1) and (2). D. is difference between (1) and (2).

There is again no direct correlation of rate with fatigue. Greater fatigue occurs when rate is slowest, save in case of boy's right hand. He preferred use of left hand but development of right-hand ability had almost resulted in ambidexterity, as the slight difference between the two records shows.

(3) *Left-handedness.*

The individual records give convincing evidence that the tapping test is a most reliable one for securing an index of left-handedness. The two girls of the regular group who were left-handed were consistently so throughout the series. There were a few trials in which scores for hands were equal. This was also true for the right-handed group. One exceptional case was X, whose record is given in Table III. Her first day's records showed a superiority of one second in rate for right hand. Her left hand was decidedly superior in later records and in final average.

We computed the percentage of left-hand to right-hand efficiency, by finding excess of time required for left-hand as compared with rate for right-hand. This gives for boys an index of 79.2%; for girls, 78.8%. This is somewhat surprising when we have two left-handed girls in group

and no boys that are left-handed. We believe the explanation is found in the records of girls I and H, that have been given, whose left hands were exceptionally poor, far exceeding in inferiority the records of the right hands of the two girls who were left-handed.

(4) *Sex Differences.*

In Table IV the individual averages for boys and girls are given. The capital letters represent individual girls, the small letters individual boys. (1) and (2) refer to first and second fifty taps. Numbers in columns are time in seconds. A. D. is average deviation.

TABLE IV

Boys					Girls				
	R. H.		L. H.			R. H.		L. H.	
	(1)	(2)	(1)	(2)		(1)	(2)	(1)	(2)
a	12.16	13.57	12.50	16.48	A	8.88	10.54	11.04	13.98
b	10.17	12.30	12.28	14.28	B	9.36	11.15	10.86	13.89
c	11.64	13.63	12.69	15.34	C	9.81	11.20	11.54	15.43
d	10.11	11.48	12.10	13.66	D	11.33	13.33	10.18	12.46
e	10.12	12.88	13.45	16.76	E	11.62	13.92	11.65	13.70
f	10.16	12.06	13.13	16.86	F	8.48	10.20	10.26	11.86
					G	11.42	13.73	13.40	16.40
					H	11.26	13.62	15.56	17.81
					I	9.75	12.50	15.37	18.40
					J	10.08	10.60	12.60	15.13
					K	10.24	12.40	12.33	15.27
					L	10.35	12.80	11.46	13.63
					M	8.74	11.30	12.04	13.68
Av.	10.72	12.65	12.67	15.56		10.10	12.10	12.17	14.74
A. D.	0.782	0.706	0.415	1.13		0.864	1.169	1.368	1.538
Total Av.....23.37			28.25			22.20		26.91	
Median.....22.73			27.99			22.25		25.37	

The time required by girls for one hundred taps was 1.179 seconds less for right hand; 1.334 seconds less for left hand than that required by boys. In each case the left hand range was greater than the right and the range of girls exceeds that of the boys.

To correct the error due to unequal distribution of sexes and to small number tested, the probable error of the dif-

ference between the averages of boys and girls was found.

P. E. of difference for R. H. 0.365

P. E. of difference for L. H. 0.447

Since the difference for right hand is 3.23 times its P. E., for left hand 3.98 times its P. E., these differences must be a valid indication of sex differentiation.

To summarize the results from the tapping test for subjects studied, we may note:

That there is marked improvement due to practice with great irregularity in early trials.

That the initial trial, or average of less than five trials, does not give a true indication of actual ability in rate of movement.

That the loss from fatigue is not directly correlated with rate, but varies irregularly; is not a distinct sex characteristic; and the index is greater for use of hand not preferred.

That there is a distinct sex differentiation in ability in tapping test in favor of girls.

That the index of right-handedness obtained, in accordance with the results of other investigators, shows more pronounced efficiency in use of preferred hand during childhood than in adult life.

V. STEADINESS OF MOTOR CONTROL

1. Apparatus

Measurement of involuntary movements was made by method similar to that described in Whipple's (24) Manual, Test 13. The brass plate had a series of holes arranged in two rows. Beginning with the one in the lower left-hand corner, the diameters of the holes were respectively 32, 28, 24, 20, 16, 12, 10, 9, 8, 7 and 6 sixty-fourths of an inch. The first five, which were in lower row, were the only ones reached within the limits of this experiment. The stylus consisted of a metallic needle one-sixteenth of an inch in diameter and one and five-eighths of an inch long, in a wooden cylindrical handle three-eighths of an inch in diameter and four inches long. The weight of stylus was twelve and a half grams. Plate, stylus, and a telephone receiver were wired in series with battery so that contact between needle and plate caused a click in the receiver. Graphic record was not made, and we recognize the source of error in the counting of strokes made by sounder when tested. The very short, rapid contacts produced such noticeable clicks, we believe the probability of errors in correct counting to be so small as not to cause significant differences in results. A stop-watch was used to time the trials.

2. Method of Conducting Test

Before the test was given each child was allowed to put the receiver to his ear and with stylus in other hand make the contact. Then it was explained to him that he was to make as few contacts as possible during his test. He stood at a distance from the table a little greater than the length of the arm from the elbow and with shoulder of arm used in front of plate. Hand and arm were free from all

support or contact with body. Plate was set flush with edge of table and adjusted at an angle such that the stylus was held perpendicular to plane of plate. Each subject was allowed three seconds to get needle in position before watch was started. Time for trial was fifteen seconds. Only two children were in room with experimenter at same time. Right hand was tested first in each hole, beginning with the largest, until the number of contacts in one hole equalled or exceeded twelve. Between tests for each hole fifteen seconds were given for resting arm. The left hand was then tested in similar manner.

3. Subjects

The subjects were same as those in tapping test. The first steadiness test was given before the practice series in tapping, the second afterward. Records are for seventeen girls and eight boys.

4. Computation of Results

The numbers of contacts made in each hole are averaged, separately for sexes, and the total number of contacts for the five holes is also given. Taking hole three as the one most satisfactorily testing the steadiness of these subjects, the average deviation of individuals from the group average was computed for right hand in hole three. The probable error of the difference between these averages for sexes was obtained, as a measure of the reliability of the sex difference.

5. Results

In Table V the records from both tests, averaged for sexes, are shown for the five holes.

TABLE V

		1	2	3	4	5	Total
Boys.....	R. H.	1.06	2.	5.12	6.43	10.75	25.36
Girls.....	R. H.	0.94	1.47	3.35	4.64	10.09	20.49
Boys.....	L. H.	3.12	4.43	5.81	8.95	10.5	32.81
Girls.....	L. H.	3.25	4.82	7.37	10.18	14.1	39.72

In this test it is generally agreed that elimination of certain factors, as distraction and moving of body, is of more importance than the repetition of tests. Children respond to the slightest external stimulus. Under seemingly most desirable conditions for experimentation one boy made a very poor record, which was somewhat explained by his statement later that his father owned an engine for cutting wood. A slight buzzing sound that came through the window was found to be from a wood yard near the school.

The trick in method, control of respiration, is not developed by the children, but the disturbance in respiration is very evident.

The movements with some are slight but almost continuous. In others there are larger movements more spasmodic. These also vary as to form. A sidewise or irregularly circular motion prevails with some, while in others there is a tendency to go forward, then back. One girl would sometimes let needle of stylus go almost its entire length through a hole and back again without a contact. This was with right hand. The same form of movement occurred with left hand, but was not so well controlled.

(1) *Practice Effects.*

When the averages of contacts made in each hole are considered separately for the two tests, both sexes show slight improvement with both hands in second test. This was not true of all individual records or for both hands in same individual. The boy who made best record of entire group in both tests made best score in first test.

(2) *Sex Differences.*

Girls are superior with right hand, boys with left. The exceedingly poor coördination with left hand by two girls may partially explain the latter result. Subject I again showed the same distance between her hands. In hole two, with right hand, she made in first and second test respectively six and two contacts; with left hand, sixteen and seventeen contacts.

Taking records for right hand in hole three we find an average deviation for girls of 2.53 contacts; for boys, 4.45 contacts. The probable error of the difference 1.77 between their averages is 0.553. The difference is 3.2 times

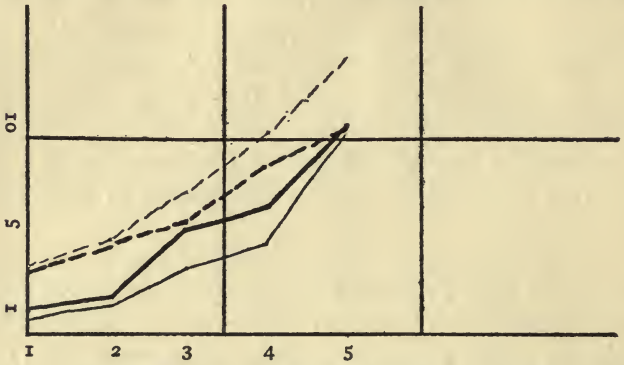

FIG. 5. Steadiness Test. Abscissa, Number of Hole. Ordinate, Averaged Number of Contacts. Boys, R. H. ———, L. H. — — —. Girls, R. H. ———, L. H. — — —.

its P. E. and indicates superiority of the girls with right hand.

(3) *Index of Right-handedness.*

The results for individuals vary from test to test with hole and with hand used. Shifts in superiority from right to left hand and vice versa are noticeable. Of the two left-handed girls as determined by tapping test, only one was left-handed in steadiness test. For boys the index of right-handedness is 77%; for girls, 51%. This shows clearly the inefficiency of left hands of certain individuals in the group of girls.

The difficulty of control in this test and the covering up of actual measurement by averages for groups that may include extreme departures from the mode invalidate many results. If a number sufficiently large could be selected, by elimination of the extremes, a norm might be established. It is to be questioned if results of Woolley and Fischer (23) from tests given a year apart and at the time children four-

teen and fifteen years old came to apply for working certificates, justify their vocational diagnosis, that for "positions requiring strength or mere rapidity of motion (particularly at fifteen years) boys would be better. For those requiring steadiness or fine motor control, girls would be better."

VI. REACTION TIMES

1. Apparatus

In measuring the reaction time of children to visual stimulus, we believed an object of interest to a child would be a better stimulus than mere geometrical designs such as are frequently used. Transfer pictures of a dog and bird were put on the milk glass plate in the screen used for displaying the stimulus. By means of an electric bulb just behind the plate and a slide with a rectangular opening, either object desired could be shown. The connections between operating keys, the D'Arsonval chronoscope, and light behind screen were such that when the experimenter pressed the keys the picture appeared and simultaneously the hand started, and when child squeezed a bulb the hand stopped.

2. Method of Conducting Test

The subject sat within a shaded compartment, just in front of screen, with arm in comfortable position, and holding a rubber bulb in right hand. Only a black curtain separated the subject from the experimenter, so that the passage of air when bulb was squeezed was sometimes heard when subject responded too soon. Caution was given that the noises incident to giving or changing stimulus were not to be heeded as significant in any way. To prevent response to noises, similar ones were given each time. The slide was pushed back and forth whether picture was changed or not. Time between changing of slide and giving of stimulus was also varied to prevent a rhythmical response. We believe, however, that the elimination of all other stimuli than the visual was not so successful but that occasional errors entered. When the time was varied between click and appearance of picture, reaction was often

made too soon. Some very short reactions may have been due to this anticipatory response.

Simple reaction times were first obtained by giving preferred object, bird to three girls, dog to one girl and one boy. After one hundred simple reactions were made, the discriminative reactions were begun. In the latter case, the subject was to respond to the object as previously given, but not to respond when the other appeared. Finally another one hundred simple reactions were made.

Some preliminary tests were given in order to find out the number of reactions that could be made during a sitting without too great fatigue and the number of sittings desirable during a laboratory period. The boy Y had been given one hundred simple reactions in the spring of 1915, responding to five circular dots. He was given a few more with the dog to note any difference that might occur because of stimulus. His interest was so keen in his first work at the laboratory that no marked difference appears and his average is made from the total number of simple reactions.

During the early preliminary trials bird or dog was chosen at random and listed. For the real tests, order of presentation was chosen by use of deck of cards. The children held themselves under rather high tension in anticipation of stimulus. This was not maintained to so great a degree during later and shorter sittings. During first simple reactions, twenty-five were made at a sitting. It was found best to give only ten presentations at one sitting, and this procedure was adopted for the discrimination reactions and for the second series of simple reactions. By giving a rest of ten minutes between sittings it was easy to get twenty-five reactions, or to give fifty presentations, during a period. This work was begun the latter part of October, 1915, and continued through March, 1916, with intervals of two to four weeks between laboratory periods.

3. Subjects

Four girls and one boy, children of professors of the University, were used in the reaction time experiment. They ranged in age from four to ten years. The four-year-old made only simple reactions.

They were evidently pleased to come to the laboratory and seemed to enjoy various tests undertaken. The reactions were interesting at first but the monotony necessarily involved proved irksome to the children. Only by short sittings and because of the pleasure of getting to the laboratory were they sufficiently stimulated to complete the tests.

4. Treatment of Data

Averages were obtained for the total number of reactions. For some subjects this number varied slightly from the one hundred planned, but we deemed it advisable to average unquestioned scores just as they were. Number of reactions, maximal and minimal reaction time, and number of errors in discrimination reactions are also listed. The reaction times are expressed in thousandths of a second, or σ.

5. Results

Tables VI and VII give our resultant values from averages for individuals and also show Gilbert's results. His averages for the ages are based on median value of ten reactions from fifty of each sex, the discrimination reaction preceding the simple.

TABLE VI

Simple Reaction Times

Indiv.	Sex	Age	Preceding Discrimination				After Discrimination				
			No. of Trials	Av. Time in σ	Max. Time	Min. Time	No. of Trials	Av. Time in σ	Max. Time	Min. Time	Gilbert's Av. in σ
Z	girl	4	105	428	1050	100					
V	girl	6	100	415	1000	100	100	239	650	40	295
X	girl	8	132	315	638	77	100	220	750	30	260
Y	boy	8	160	263	600	160	100	130	310	20	245
W	girl	10	102	250	640	110	100	127	350	20	225

TABLE VII

DISCRIMINATION REACTIONS

Indiv.	Sex	Age	No. of Trials	Av. Time in σ	Max. Time	Min. Time	No. of Errors	Gilbert's Av. in σ
V	girl	6	77	404	1150	60	11	510
X	girl	8	140	324	1300	80	13	475
Y	boy	8	100	253	850	40	8	480
W	girl	10	84	187	650	20	8	415

The simple reaction time for trials preceding the discrimination are longer even than the discrimination reaction times, with the exception of the eight-year-old girl, and much longer than those found by Gilbert for subjects of same age. These latter were made after his discrimination reactions, but his trials were so few the effect of practice does not sufficiently explain the difference. His results are the averages for a large number of subjects and based on the median value for a subject, so not actually comparable with the individual records we have listed.

It was to be expected that the greater practice would make the simple reaction times for the last series shorter than the first, but it was surprising to note that in two cases they are much shorter than the time Gilbert found for the subjects seventeen years old, boys 147; girls 163. This is representative of the normal simple reaction time of adults found by other investigators.

As a child more fully understood just what was expected of her, and also realized that other children were doing the same thing, a spirit of competition developed. This was not purposely encouraged but was a natural development evidenced by such remarks as, "Do I do as well as the others?" and, "Oh, I tried not to go too soon." This latter remark also indicates the anticipatory state in which the child was so ready to respond that the reaction would often have been made whether the stimulus appeared or not. The objective evidence of this was given when the time of giving stimulus was varied and reactions were made too soon.

The discrimination times reported by Gilbert are rather

long, but one who has noted the lengthened period of adjustment necessary for young children would expect such from the few trials. The records we have obtained compare most favorably with those for adults. Gilbert's average in discrimination for those seventeen years old is for boys 305; for girls 315. The number of errors we found was not excessive. Premature responses were not so frequent as in the simple reactions. The inhibition that prevented response to wrong stimulus seems carried over into inhibition of premature responses. The extremely short minimal times seem to be partly due to chance. Subject W once remarked, "I'm so glad it was a bird. I believe I would have pressed if it had been a dog."

While for these few subjects there is increasingly shortened reaction with increasing age, the averages approximate much more closely those for adults than results in other motor tests have done. Usually the adult records are based on fewer trials and perhaps upon more fatiguing periods of experimentation than were practical for the children. A most interesting problem would be a prolonged comparative study of reaction times for different ages, determined under same conditions.

VII. ACCURACY OF MOVEMENT

1. Apparatus

A wooden board 26 by 37 inches was painted black and sanded to prevent sliding of bags. On this board four concentric circles were described in white paint. The central circle had a diameter of six inches; the others, respectively, twelve, eighteen, and twenty-four inches. The board was divided into halves, both horizontally and vertically, by two straight lines intersecting in the center of the system of circles. There was an adjustable support, so the board could be inclined at such an angle that the bags would fall perpendicularly upon it. The bags were circular, three and a half inches in diameter, filled with rice, and weighed fifty-four grams.

2. Method of Conducting Test

The board was placed upon the floor against a wall. Each subject stood at a distance of six feet from the lower edge of board, and in such position that the arm used was in line with the vertical line upon board. His aim was the center of the circles where the straight lines intersected. Freedom in manner of throwing was given as to tossing or overhand throw. Only occasionally was the latter used. Tossing the bag proved to be a more accurate method and was adopted by all.

Groups of twelve children, six boys and six girls, will be designated according to intervals between practice. The five-days-a-week group were given ten throws with each hand, the right preceding, on each school day for the first three weeks in December, between eleven and twelve o'clock.

The Tuesday-and-Thursday group were practiced from

ten to eleven o'clock on the days mentioned until the total number of throws equalled that of the first group.

The once-a-week group were given twenty throws with each hand on Thursdays between nine and ten o'clock.

The once-in-two-weeks group had ten throws with each hand on Tuesdays from nine to ten o'clock. During the later practice periods these were given fifteen throws with each hand. They were somewhat younger than the once-a-week group and because of fatigue effects it was thought best to give only ten throws at the beginning, but later the fifteen throws seemed desirable.

The Christmas holidays made an interval of two weeks without practice for all the groups save the first. In each case periods were arranged so that one hundred and forty throws were made with each hand, the right preceding. If a child was absent more than three times, he was eliminated.

3. Sources of Error

Since the line of motion varied from throw to throw, the bag did not fall perpendicularly upon the board each time. When it did, it remained where it first touched. With varying trajectories given by the tosser, the bag met the board at varying angles. This, together with force of throw, caused the bag to skid or to turn over at times. By noting exact difference this made in score of several individuals during a number of practice periods, it was found that the error was never greater than one on a single throw or three for a practice period with one hand. There was rarely a change in score unless bag fell in line with center and it is evident that here the errors on the upper side tend to counter-balance those on the lower side.

An attempt was then made to ascertain any constancy as to portion of board struck by individual thrower. There was no regularity as to direction of error for the subjects who were studied for this purpose. We believe the scores are representative, the slight residue of errors from these sources being as probable for one subject as another.

4. Method of Scoring and Computation of Results

If the bag fell within the inner circle it touched the central point and the score recorded was four; within the next circle, three; the next, two; the outer circle, one. If partly in one, then the score was recorded for that circle within which it clearly lay. Anywhere outside the outer circle was scored zero. The total individual score for a practice period was divided by the number of throws made and the quotient recorded. The records for subjects within a group were averaged for each practice period. The curves were drawn according to these averages. Final averages for the sexes were obtained for group comparisons. The average daily deviations from the final average and the probable errors were also calculated as a measure of reliability of score.

5. Results

The tables VIII, IX, X, and XI give the average performance of each group, a statement of the average deviation, and the probable error of the difference between the averages for the sexes.

5-Days-a-Week Group

The average age of this group was six years, seven months for girls, within a range of one year, one month; for boys, six years, two months, ten days, within a range of five months. Records given are for five girls and five boys.

While the individual differences in efficiency are largely eliminated in the consideration of the averages for the groups as a whole, they do enter into the computation of rate and amount of improvement for a particular group in a way that causes a defect so far as practice effects are concerned. The majority in a group might show slight improvement on one day, yet if the best performers of the preceding day chanced to make unusually poor throws, the final average for that day would be lower.

The experiments were necessarily extended throughout

TABLE VIII

SHOWING THE DAILY AVERAGES FOR THE FIVE-DAYS-A-WEEK GROUP

Day	Girls		Boys	
	R. H.	L. H.	R. H.	L. H.
1	1.5	1.475	2.033	1.3
2	1.9	0.98	1.633	1.3
3	1.725	1.475	1.9	1.2
4	2.075	1.25	1.633	1.15
5	1.6	1.2	1.62	1.06
6	1.4	1.2	1.66	0.98
7	1.833	1.433	1.383	1.116
8	1.7	1.2	1.48	1.38
9	1.9	1.6	1.54	1.06
10	1.6	1.4	1.55	1.133
11	1.56	1.32	1.283	1.083
12	1.72	1.66	1.35	1.00
13	1.44	1.34	1.416	1.25
14	1.4	1.15	1.54	1.26
Total.....	23.353	18.683	22.021	16.272
Av.....	1.668	1.334	1.573	1.62
A. D.....	0.168	0.148	0.148	0.102

Difference between averages for R. H. 0.095
L. H. 0.172
Probable error of R. H. difference 0.0945
L. H. difference 0.0759

such a long period absences were unavoidable. We could not eliminate all who were absent for any period because it reduced the groups too much for study. The absence of a thrower who was above the average ability reduced the score for that day as compared with the preceding practice period.

In many individuals there was a continued but irregular improvement. This was shown especially by those who were poor in coördination at the beginning, frequently failing to hit the board.

The curve for the right hand of girls is similar to the general learning curve, with more irregular gains during the first five days. On the sixth and last day the records are inferior to that for first day. With the left hand there are fluctuations of considerable magnitude. On three days later in the series records equalled or excelled that of the

first day, but elsewhere no improvement was shown and the final average is less than the score for first day.

The initial record for boys was superior to any later record and to final average for boys' right hand. With left hand there were only three days in which improvement

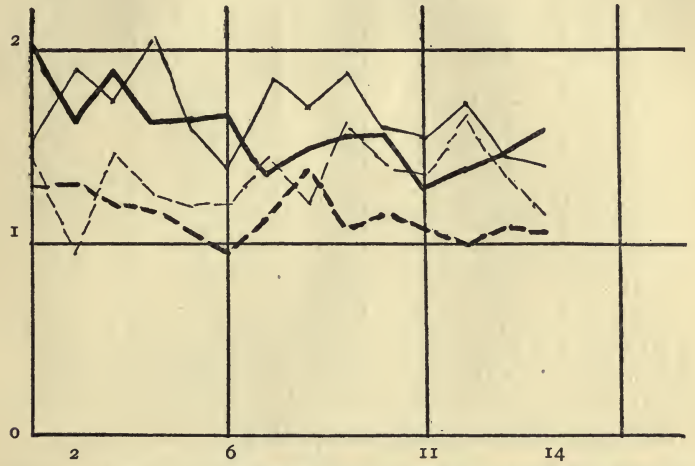

FIG. 6. Five-Days-a-Week Group. Abscissa, Practice Periods. Ordinate, Daily Score. Boys, R. H. ———, L. H. — — —. Girls, R. H. ———, L. H. — — —.

was shown over the first and the final average was inferior.

There is a possibility that in this group the excitement and overstrain often produced by preparations for Christmas caused the decrease in efficiency during the trials for the last week.

2-Days-a-Week Group

The average age for this group was six years, five months, seven days for girls; six years, two months, five days for boys. Five boys and four girls were included in final records.

The curve for girls shows gradual gain with varying fluctuations. Again the boys show almost maximal efficiency on the first day. With the right hand there is gradual improvement through the fourth day with an irreg-

TABLE IX

SHOWING THE DAILY AVERAGES OF THE TWO-DAYS-A-WEEK GROUP. TUESDAYS AND THURSDAYS

Day	Girls		Boys	
	R. H.	L. H.	R. H.	L. H.
1	1.275	0.95	1.616	1.483
2	1.36	1.08	1.683	1.05
3	1.25	1.25	1.733	1.216
4	1.70	1.275	1.75	1.066
5	1.50	1.10	1.466	1.05
6	1.38	1.16	1.533	1.066
7	1.275	1.30	1.586	0.966
8	1.35	1.30	1.58	1.16
9	1.325	1.00	1.46	1.18
10	1.30	1.30	1.48	1.16
11	1.90	1.125	1.30	1.10
12	1.24	1.180	1.60	1.10
13	1.65	1.625	1.616	1.116
14	1.333	1.033	1.683	1.25
15	1.426	1.475	1.366	1.483
Total.....	21.263	18.153	23.432	17.446
Av.....	1.417	1.210	1.562	1.163
A. D.....	0.144	0.134	0.102	0.106

Difference between averages for R. H. 0.145
L. H. 0.047
Probable error of R. H. difference 0.0745
L. H. difference 0.0721

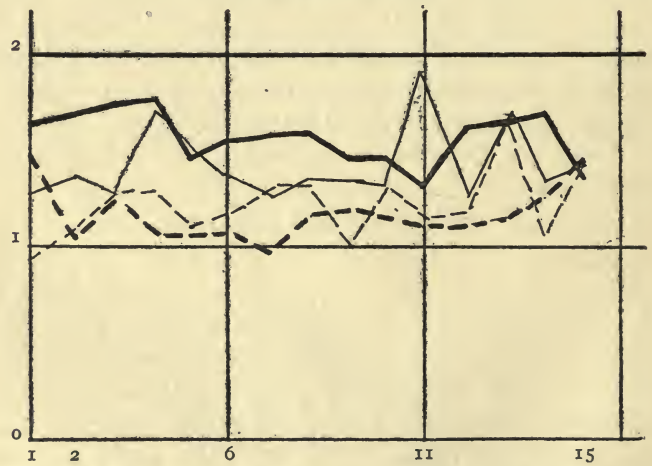

FIG. 7. Two-Days-a-Week Group. Abscissa, Practice Periods. Ordinate, Daily Score. Boys, R. H. ———, L. H. — — —. Girls, R. H. ———, L. H. — — —.

ular decline until the thirteenth day, when the score equals that of initial records. The average results for both hands are less than the initial scores.

There was seemingly no lack of interest on the part of the boys but there is an indication that they did not put forth their best efforts. There was sometimes a tendency to attempt a fancy throw.

Once-a-Week Group

The average age of this group was seven years, four months, eighteen days for girls; seven years, eight months, five days for boys. The records of six girls and six boys are reported.

TABLE X

SHOWING DAILY AVERAGES FOR ONCE-A-WEEK GROUP, HAVING TWENTY THROWS WITH EACH HAND IN A PRACTICE PERIOD

Day	Girls		Boys	
	R. H.	L. H.	R. H.	L. H.
1	1.483	1.233	1.683	1.616
2	1.333	1.216	1.36	1.73
3	1.366	1.275	1.54	1.425
4	1.875	1.508	1.54	1.42
5	1.537	1.325	1.608	1.375
6	1.36	1.06	1.591	1.616
7	1.61	1.43	1.558	1.45
Total.....	10.564	9.047	10.881	10.632
Av.....	1.509	1.292	1.554	1.519
A. D.....	0.141	0.11	0.063	0.115

Difference between averages for R. H. 0.045
L. H. 0.227
Probable error of R. H. difference 0.0574
L. H. difference 0.0612

A substantial but somewhat irregular improvement is shown by the girls. The boys show the high initial efficiency that has characterized the boys of the other groups, with but slight evidence of improvement shown either by daily averages or final average results.

Once-in-Two-Weeks Group

For the girls of this group the average age was seven years, one month, within a range of one year, one month;

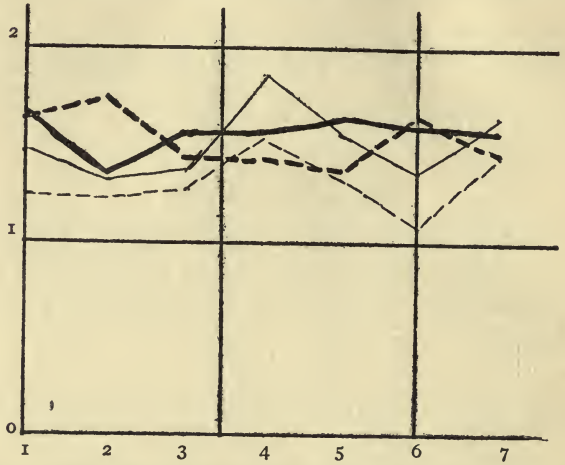

Fig. 8. Once-a-Week Group. Abscissa, Practice Periods. Ordinate, Daily Score. Boys, R. H. ——, L. H. — — —. Girls, R. H. ——, L. H. — — —.

for the boys the average age was six years, three months, fifteen days, with a range of nine months. The records are given for six girls and five boys.

With right hand there is a decrease in efficiency on second day for boys, on second, third and fourth days for girls. Then a gradual rise in curve shows slow but fairly regular improvement.

The left hands show much more instability. The average result for girls with left hand was less than score for first day and the boys show very slight improvement. In this group there was no subject who gave evidence of any desire to use left hand, but rather a marked preference for right.

(1) *Practice Effects.*

The indications are that the limit of improvement has not been reached. The rate is so lacking in uniformity and varies so considerably for different groups that it is difficult

TABLE XI

SHOWING DAILY AVERAGES FOR ONCE-IN-TWO-WEEKS GROUP

Day	Girls		Boys	
	R. H.	L. H.	R. H.	L. H.
1	1.516	1.35	1.4	1.1
2	1.433	1.32	1.12	0.76
3	1.33	1.216	1.64	0.8
4	1.4	1.	1.7	1.26
5	1.86	1.26	1.6	0.975
6	1.744	1.255	1.573	1.253
7	1.766	1.033	1.72	1.44
8	1.84	1.44	1.7	1.25
9	1.84	1.26	1.453	1.2
10	1.7	1.188	1.706	1.253
11	1.73	1.366	1.6	1.266
Total.....	18.159	13.688	17.212	12.557
Av.....	1.65	1.244	1.564	1.141
A. D.....	0.168	0.098	0.131	0.28

Difference between averages for R. H. 0.086
L. H. 0.103
Probable error of difference for R. H. 0.084
L. H. 0.124

to get any satisfactory indication of acceleration or retardation of improvement. The irregularities may be accounted

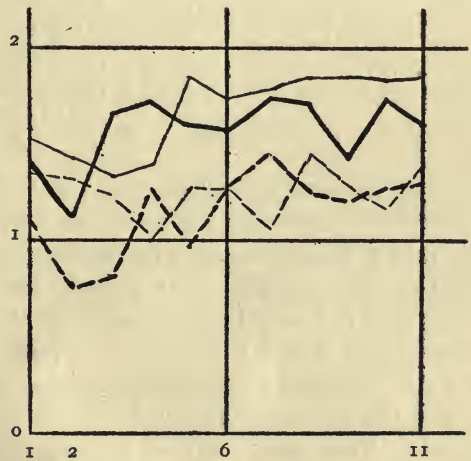

FIG. 9. Once-in-Two-Weeks Group. Abscissa, Practice Periods. Ordinate, Daily Score. Boys, R. H. ———, L. H. — ——. Girls, R. H. ———, L. H. — — —.

for in part by differences in initial ability, in native capacity to improve, and in coöperation of subject.

The amount of improvement as measured by comparison of first day's score with final average is more clearly shown in the following tables. The percentage columns represent the percentage of initial efficiency which the final average is.

TABLE XII

SHOWING THE RELATION BETWEEN THE INITIAL SCORES AND FINAL AVERAGES FOR RIGHT HANDS OF ALL GROUPS

Group	Girls			Boys		
	1st Day	Av.	% of Improvement	1st Day	Av.	% of Improvement
5-Days-a-Week.....	1.5	1.668	11.2	2.033	1.573	−22.6
2-Days-a-Week.....	1.275	1.417	11.1	1.616	1.562	− 3.34
1-Day-a-Week.....	1.483	1.509	1.75	1.683	1.554	− 7.66
1-Day-in-2-Weeks.....	1.516	1.65	8.83	1.4	1.564	11.7

TABLE XIII

SHOWING THE RELATION BETWEEN THE INITIAL SCORES AND FINAL AVERAGES FOR LEFT HANDS OF ALL GROUPS

Group	Girls			Boys		
	1st Day	Av.	% of Improvement	1st Day	Av.	% of Improvement
5-Days-a-Week.....	1.475	1.334	− 9.4	1.3	1.62	−10.6
2-Days-a-Week.....	0.95	1.21	27.3	1.483	1.163	−21.3
1-Day-a-Week.....	1.233	1.292	4.78	1.616	1.519	− 6
1-Day-in-2-Weeks.....	1.35	1.244	7.85	1.1	1.141	3.72

The negative improvement shown in boys' records invalidates somewhat conclusions for groups as a whole. The once-in-two-weeks group shows greater improvement in consideration of entire group. The girls in the two-days-a-week group have less initial ability, hence greater percentage of improvement, if both hands are considered.

From the percentages of improvement given for girls, it is evident that the short and frequent practice periods are more valuable. The group having greatest number of throws during a practice period with only one period a week shows very little improvement. The co-operation of the

subject is so closely related to the improvement, for the determination of the most economical distribution of the practice periods, it seems necessary to stimulate the subject sufficiently for complete response to the task. Unless this can be accomplished in frequent practice periods, then longer intervals are more desirable.

(2) *Index of Right-handedness.*

By computing the percentage of efficiency of the left hand to the right hand we obtain for the various groups the following indices:

	Boys	Girls
5-Days-a-Week	73 per cent.	79 per cent.
2-Days-a-Week	74 per cent.	85 per cent.
1-Day-a-Week	96 per cent.	85 per cent.
1-Day-in-2-Weeks	73 per cent.	75 per cent.

In the Once-a-week group the large percentage for boys is due, doubtless, to the consistent superiority of left hand in one subject. In same group two girls were slightly superior with left hand in final average. In Two-days-a-week group the left hand of one girl excelled her right hand in the majority of throws. From 73% to 80% efficiency with left hand is characteristic of groups having no left-handed subjects. This can not be accepted as an absolute index since right hand preceding left may condition it to some extent.

(3) *Sex Differences.*

According to the final averages the girls are superior with both hands in the Five-days-a-week and Once-in-two-weeks groups and for left hand in Two-days-a-week group. In other cases the boys excel.

The probable errors show that the differences between the averages for the sexes are insignificant except for left hand of Five-days-a-week and Once-a-week groups. In the former case the difference of 0.172 in favor of girls is 2.26 times its P. E. There was one girl in this group who showed slight superiority with left hand.

In the second case the difference of 0.227 in favor of boys is 3.7 times its P. E. One of these boys was decidedly left-

handed. Aside from these differences that the particular cases might explain there is no distinct sex differentiation evidenced by average results.

There is a noticeable sex difference in the course of improvement from day to day. In all groups of boys except the Once-in-two-weeks group, the final average was less than the initial score and the maximal score was made either on first day or in early trials. The girls follow more closely the usual course in learning and with the exception of two left-hand averages, make better final averages than initial records. Maximal efficiency is not attained until fourth day or often much later in the series.

This suggests continued co-operation on part of girls throughout the series, while the boys failed to respond with the same interest during later trials. This is most noticeable in the Five-days-a-week group.

The curve of boys who practiced only once in two weeks resembles that of the girls. Maximal score is not made until seventh day with right hand and on last day with left hand. Here the longer period intervening between practice periods may cause the sustained interest and there is gradual improvement.

It is also suggested that the initial performance of boys represents more practice in this activity. Just how much it is not possible to determine. Some questions were asked as to previous motor activities but the answers were too indirect to be satisfactory. Rubber balls for bouncing seemed to be the chief kind with which the girls were acquainted. In a few cases girls spoke of playing "catch" with their young brothers.

There is certainly an indication that the emotional attitude greatly affects progress in learning and that sex differentiation is most distinct in the affective elements.

VIII. PREFERENCE IN SIDE OF BODY USED

In both of the practice series in motor coördination preference in hand used was very evident. At this age the three types are readily recognized, the decidedly right-handed, the practically ambidextrous, and those distinctly preferring left hand. In the second class a given hand is usually preferred for certain activities, such as writing with one hand and throwing a ball with the other. It becomes an important problem of school management to determine whether the left-handed person should be left alone or ambidexterity cultivated.

Ballard (2) made three investigations into the effect of interference with left-handedness, finding the percentage of stammerers among the frankly left-handed to be 2%, the same as among school children as a whole. But among the left-handed who have been forced to write with right hand this increases to 17%. He also reports a distinct difference in intelligence between the two classes of left-handed children, those upon whom ambidextral training has been forced being clearly inferior, though coming as a rule from better homes.

To investigate the preference in side of body used, a number of children were examined in the school in which the aiming test was conducted.

All the children of a first grade were taken to the gymnasium, and one child at a time, standing near center of hall, was asked to kick a light football to another at the other end of room, who in turn should kick it back. The foot used was noted. Out of thirty-eight children, two boys and one girl used the left foot. One of the boys, Otto, was decidedly left-handed, writing with his left hand, and no attempt had been made to force him to use right hand. The other boy and the girl wrote with right hand and had a

slight balance in favor of right hand in aiming test, though on many days the left hand excelled. One left-handed girl, Anna, among this group used her right foot. She also writes with right hand. Her score in aiming was very low, but left hand was slightly superior.

To discover any preference as to direction in turning, a "soldier" game was used. Again we went to the gymnasium so as to have a large space with similar surroundings on each side. There were windows on one side only, so the back was turned to windows, thus having a blank wall in front and at either side. Two straight lines were drawn upon the floor in white crayon and the child was asked to walk like a soldier from one to the other, turn, and walk back again. This was repeated four times. The observer stood about five feet directly behind the subject at starting. No one was within his field of vision until after he had turned. Sometimes there were only two and never more than five children were in the gymnasium at one time. Results from fifty-five children between the ages of five and eight years are as follows:

The number consistently turning to left was 30; to right 14. There were—

5 who turned to left 4 times; to right 1 time.
2 who turned to left 3 times; to right 2 times.
2 who turned to left 2 times; to right 3 times.
2 who turned to left 1 time; to right 4 times.

Of the three decidedly left-handed subjects as determined in aiming, two consistently turned to left, the boy, Otto, mentioned in kicking of ball, and the girl, Anna. One boy, William, who writes with left hand and made the best left-handed score of entire group in aiming, his left hand failing only once to excel his right, turned to left only twice out of five times.

Since only 20% of number show inconsistency, it is evident that there is decided preference as to direction of turn. The effect of training and imitation would have to be considered in a more complete analysis. Interference effects

might explain somewhat the lack of correlation between preferred hand and preferred side in turning. The position of thumb in clasping of hands, with fingers interlaced, is reported by adults to be distinctly preferential. There is scarcely a dissenting voice as to the awkwardness felt in placing the other thumb than desired one on top. Among the few adults tested, as a rule, the right-handed person puts the left thumb on top and vice versa. This seems to give the favored hand a more advantageous position for the clasping in which it takes the aggressive part.

Results from sixty-four children are given. These children were not only asked to clasp hands and position of thumbs noted as each one passed slowly by, but in a song taught by their teacher they were required to sit with clasped hands resting on desks. The observer passed along the aisles during the singing of this song to note again the manner of clasping. Position of thumb was same in each case as in previous clasping.

28—R. H. in writing—put R. thumb on top.
32—R. H. in writing—put L. thumb on top.
3—L. H. in writing—put R. thumb on top.
1—L. H. in writing—put L. thumb on top.

There is consistency and preference in form of clasping, but the almost equal distribution of right-handed group shows no direct correlation with favored hand in other activities.

The importance of the development of motor activities of young children makes the question of motor methods and of interference with use of preferred hand a vital one in educational theory. While we need much more data as to real effects of interference and the advisability of cultivating right-handedness, the data set forth certainly leads to the conclusion that there is a marked preference as to side of body used by an individual in his various activities, even such as environmental compulsion or suggestion can not explain.

IX. GENERAL SUMMARY AND CONCLUSIONS

1. Rate of Voluntary Movement

Previous research has shown marked increase in rate of movement with increasing age. The results we have obtained for young children compared with those established for subjects of more advanced age accord with this finding.

There is gradual improvement due to practice but great irregularity in early trials, the average rate being attained by fourth or sixth day but maximal efficiency is not reached until late in the series.

We seem justified in concluding that the initial trial, or average of less than five trials, does not give a valid indication of actual ability, of fatigue effects, or of sex differences. This corresponds to Kelly's (12) conclusion for children from four to fourteen years old, that "there is no trustworthy correspondence between the work of the first ten seconds and the child's real mental power so far as it may be applied to any practical problem in life."

No direct correlation of fatigue and rate is found, nor is there a distinct sex differentiation in loss by fatigue. The index of fatigue is greater for use of hand not preferred.

There is a distinct difference between the sexes in ability in tapping test, favoring the girls in this group, which has far greater variation among girls with two subjects at each extreme, while the boys cluster closely about the average. This leads to no generalization concerning sex differences.

The index of right-handedness for girls is 78%; for boys, 79%. Compared with Smedley's (19) 82% at age of nine years, 89% at age of eighteen years, and with Wells' (21) average index of 90% for adults, this indicates more pronounced efficiency of right hand in childhood.

2. Steadiness of Motor Control

There is great variation in the outcome of this test, with shifting superiority from one hand to the other. There is evidence of but slight improvement from repetition of test.

The girls excelled with right hand, the boys with left hand. The best individual score in each test was made by a boy.

The index of right-handedness is lower than in tapping and varies from test to test, so that it is not very reliable as indicating efficiency of either hand.

3. Reaction Times

There is marked improvement due to practice in quickness of response to visual stimulus. The simple reactions preceding the discrimination were longer than the discrimination, those following were shorter.

Premature responses are more frequent in simple reactions, due, perhaps, to inhibitory effects of discrimination reactions.

There is an increasingly shortened reaction time with increasing age for subjects studied, but averages obtained for children approximate much more closely those for adults than is shown in results of other motor tests. The three subjects from eight to ten years old have quicker reactions than the seventeen-year-old subjects tested by Gilbert (8) and McDonald (15).

We find less difference between the simple and discrimination reaction times than the results of these investigators show.

4. Accuracy of Movement

The rate and amount of improvement in accuracy of movement vary considerably for sexes and for groups with different intervals between practice.

The aiming test is most reliable for indicating left-handedness, the index varying from 73% to 80% for groups having no left-handed subjects and reaching 96% for group having a subject consistently left-handed.

There is no distinct sex differentiation evidenced by average results, except for left hand of two groups which particular cases of superiority with left hand explain.

The sex difference in course of improvement from day to day is so great that comparison of groups other than by sexes is of little value.

The girls show a gradual improvement, with irregularities in left-hand progress, and maximal efficiency is not attained until fourth day or often much later in the series.

Short and frequent practice periods are more valuable for girls. The group having greatest number of throws during a practice period with only one practice a week shows but little improvement.

The boys make higher initial scores than final averages in all groups except the Once-in-two-weeks group. Maximal score was made on first day or in early trials.

The boys of Once-in-two-weeks group have similar curve to girls and maximal score is not made until seventh day with right hand and fourth to last day with left hand.

This suggests better sustained interest of boys with longer intervals between practice periods.

There is an indication of a distinct sex difference in the emotional attitude towards motor activities, with more complete response on part of boys in beginning showing negative improvement; but a sustained interest on part of girls, resulting in gradual progress.

5. Preference in Side of Body Used

There is a decided preference as to hand or foot used in free motor activities: in direction of turning and in position of fingers when hands are clasped.

There is no direct correlation of favored hand with favored side used in other activities, but more consistency in preference of left-handed group for left side than in preference of right-handed group for right side.

The results for these groups could not be universally applied as representative of the motor abilities of children.

They certainly suggest the need of experimental evidence, upon which to base the solution of practical educational problems.

If educational guidance is to serve as a basis for vocational guidance and such tests are to be applied for selective purposes, beginnings having already been made in these lines, the significance and reliability of such tests are most important.

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